STUDIES ON THE NOMENCLATURE AND CLASSIFICATION OF THE BACTERIA. IV. SUBGROUPS AND GENERA OF THE COCCACEAE

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Family 1. **Coccaceae** Zopf, 1884, p. 45, emended Migula 1894

Synonyms:

Sphaerobacteria Cohn, 1872, p. 146
Coccaceen Zopf, 1884, p. 45
Coccogenae Trevisan, 1885, p. 92
Coccacei Schroeter, 1886, p. 143
Coccobacteria Schroeter, 1886, p. 143
Sphaerobacteries Maggi, 1886, p. 81
Kokkaceen Hueppe, 1886
Coccacees Mace, 1897, p. 334

Cells usually spherical, sometimes somewhat elongated just before division, or when occurring in pairs or groups cells may be somewhat flattened on sides in contact. Never containing granules of sulphur, nor with bacteriopurpurin. Many species develop a pigment. Some species are motile by means of flagella. Cells frequently remaining in groups after division, forming chains, regular packets or irregular masses. Spore production doubtful, having been reported for but one species. Pseudoplasmodium never produced. Growth energy not secured by the oxidation of ammonia or nitrites.

The following names have been applied to groups designated as subfamilies, tribes and subtribes of the Coccaceae.

Ascococceae De Toni and Trevisan, 1889, p. 1037
Eu-Ascococceae De Toni and Trevisan, 1889, p. 1037
Gaffkyeae De Toni and Trevisan, 1889, p. 1042

Micrococceae De Toni and Trevisan, 1889, p. 1067
Sarcineae Trevisan, 1879, p. 136
Mycococcaceae Hansgirg, 1888, p. 266
Eucoccaceae Hansgirg, 1888, p. 267
Cystococcaceae Hansgirg, 1888, p. 266
Streptococceae De Toni and Trevisan, 1889, p. 1051
Homococcaceae Fischer, 1897, p. 32
Allococcaceae Fischer, 1903, p. 59
Metacoccaceae Winslow and Rogers, 1905, p. 669
Paracoccaceae Winslow and Rogers, 1905, p. 669

It is evident that, while many generic names have been proposed for cocci, very few authors have defined subfamilies, tribes or subtribes. Apparently the first effort was that of De Toni and Trevisan (1889, p. 1035). The following key to their tribes and subtribes indicates their grouping.

It will be noted that the chief emphasis throughout the classification is placed upon the development of cysts and capsules and upon cell groupings.

Key to Tribes of Coccogenae. De Toni and Trevisan

A. Cocci associated in families in bladder-like, gelatinous masses or cysts. Tribe I. *Ascococceae*
  I. Cocci separated from each other in the mucus of the matrix.
    a. Cocci destitute of special cysts, in families, in a common cyst. Subtribe I. *Eu-Ascococceae*
    b. Cocci borne in special cysts. Common cysts absent. Subtribe II. *Gaffkyeae*
  II. Cocci loosely united in a mucous matrix. Cysts generally delicate at length breaking apart. No special cysts. Subtribe III. *Amoebobacterieae*
B. Cocci associated in families of one or many layers, surrounded by a more or less evident mucous matrix. . . . . Tribe II. *Sarcineae*
C. Cocci in moniliform chains. Large arthrospores developing in the filaments or at the tips. . . . . Tribe III. *Streptococceae*
D. Cocci not in capsular cysts or sheaths, nor in moniliform chains. Small endospores in the cells. . . . . Tribe IV. *Micrococceae*

The classification of Winslow and Rogers (1905) separates the *Coccaceae* into two subfamilies, *Metacoccaceae* and *Paracoccaceae*. The subfamily *Metacoccaceae* is defined to include

the genera *Micrococcus*, *Sarcina* and *Rhodococcus*. The description given (1905, p. 669) is as follows: "Facultative parasites or saprophytes. Thrive best under aërobic conditions. Grow well on artificial media, producing abundant surface growths. Planes of fission often at right angles; cells aggregated in groups, packets or zoogloea masses." In later descriptions (1906, p. 845, and 1908, p. 258) they have added "Generally decolorize by Gram. Pigment yellow or red."

The subfamily *Paracoccaceae* (1905, p. 669) is defined to contain the genera *Diplococcus*, *Ascococcus*, *Streptococcus*, *Albococcus* and *Aurococcus*. The description is: "Parasites (thriving only, or best, on or in the animal body), thrive well under anaërobic conditions. Many forms fail to grow on artificial media; none produce abundant surface growths. Planes of fission generally parallel, producing pairs, or short or long chains." Later (1906, p. 545, and 1908, p. 249) the diagnosis was amended by adding: "never packets. Generally stain by Gram. Produce acid in dextrose and lactose broth. Pigment, if any, white or orange."

The careful work of the Winslows indicates that they have probably secured a logical basis for separation of the genera of the *Coccaceae* into two groups. It is not quite so certain, however, that the genera which they include are all that may be recognized. Perhaps the genus *Siderocapsa* Molisch is sufficiently distinct from the other cocci to require a third group in which to place it.

As has been previously shown (Buchanan 1915, p. 530) the subfamily names *Metacoccaceae* and *Paracoccaceae* are invalid in form, and might well be replaced by the tribal names *Micrococceae* Trevisan and *Streptococceae* Trevisan, with an emended diagnosis.

The three tribes recognized may be differentiated by reference to the following key in which are noted some of the distinguishing characters.

Key to tribes of Coccaceae

I. Not epiphytes, not causing the deposition of iron upon capsules.

A. Commonly parasitic, in some forms saprophytic, usually thriving well under anaërobic conditions, not commonly producing luxuriant growths on artificial media, many forms failing to grow except upon special media. Cells in pairs, chains or irregular masses, never regular packets. Gram-positive, with exception of a few strict parasites. Acid usually formed in dextrose and lactose broth. Pigment white, orange or absent.
Tribe I. *Streptococceae*

B. Saprophytes, or facultative parasites. Usually grow best under aërobic conditions, producing abundant to luxuriant growth on artificial media. Planes of fission often at right angles: Cells aggregated in groups, packets or zoogloeal masses. Usually Gram-negative. Pigment as a rule yellow, red or orange.
Tribe II. *Micrococceae*

II. Epiphytes, usually on leaves and stems of water plants. Iron oxid deposited upon the capsule.....Tribe III. *Siderocapseae*

The following list of generic, subgeneric and pseudogeneric names have been used for various cocci.

Merismopedia Meyen, 1839, p. 67 in part
Sarcina Goodsir, 1842, p. 432
Microhaloa Kützing, 1842, p. 169
Sphaerococcus Kützing, 1843, p. 408
Botryococcus Kützing, 1849, p. 892
Micrococcus Cohn, 1872b, p. 151
Microsphaera Cohn, 1872a, p. 237
Diplococcus Weichselbaum, 1874, p. 5
Ascococcus Billroth, 1874, p. 13
Coccobacteria Billroth, 1874, p. 1
Coccoglia Billroth, 1874, p. 7
Coccos Billroth, 1874, p. 4
Diplococcos Billroth, 1874, p. 5
Gliacococcos Billroth, 1874, p. 5
Megacoccos Billroth, 1874, p. 16
Mesococcos Billroth, 1874, p. 6
Micrococcoglia Billroth, 1874, p. 14
Micrococcos Billroth, 1874, p. 6
Monococcos Billroth, 1874, p. 5

Petalococcos Billroth, 1874, p. 6
Streptococcos Billroth, 1874, p. 10
Streptomicrococcos Billroth, 1874, p. 11
Ascococcus Cohn, 1875, p. 154
Leuconostoc Van Tieghem, 1878, p. 198
Gonococcus Neisser, 1879, p. 497
Chlamydatomus Trevisan, 1879, p. 137
Urosarcina Miquel, 1879, p. 517
Merista Van Tieghem, 1884, p. 1114
Staphylococcus Rosenbach, 1884, p. 19
Streptococcus Rosenbach, 1884, p. 22
Gaffkya Trevisan, 1885, p. 105
Neisseria Trevisan, 1885, p. 105
Arthro-Streptokokkus Hueppe, 1886, p. 145
Askokokkus Hueppe, 1886, p. 145
Hyalococcus Schroeter, 1886, p. 152
Leucocystis Schroeter, 1886, p. 152
Botryomyces Bollinger, 1888, p. 177
Pediococcus Balcke, 1884, p. 183
Pseudodiplococcus Bonome, 1888 p. 321
Haematococcus Babes, 1889, p. 81
Babesia De Toni and Trevisan, 1889, p. 1054
Bollingera De Toni and Trevisan, 1889, p. 10[illegible]
Perroncitoa Trevisan, 1889, p. 29
Schuetzia Trevisan, 1889, p. 29
Diplokokkus Baumgarten, 1890, p. 127
Tetracoccus Billet, 1890, p. 24
Endostreptokokkus Hueppe, 1891, p. 33
Mikrokokkus Hueppe, 1891, p. 33
Pediokokkus Eisenberg, 1891, p. 25
Sphaerokokkus Eisenberg, 1891, p. 50
Rhodococcus Zopf, 1891, p. 28
Iodococcus Miller, 1892, p. 63
Jodococcus Miller, 1892, p. 63
Makrokokkus Miller, 1892, p. 73
Pyococcus Ludwig, 1892, p. 27
Eucoccus Migula, 1895, p. 16

Euplanococcus Migula, 1895, p. 19
Euplanosarcina Migula, 1895, p. 20
Eusarcina Migula, 1895, p. 18
Planococcus Migula, 1894, p. 236
Planosarcina Migula, 1894, p. 236
Lactococcus Beijerinck, 1901, p. 213
Carphococcus Hohl, 1902, p. 338
Karphococcus Hohl, 1902, p. 338
Pseudosarcine Maze, 1903, p. 887
Mesococcus Smith, 1905, p. 174
Monococcus Smith, 1905, p. 174
Pneumococcus Schmidlechner, 1905, p. 291
Albococcus Winslow and Rogers, 1906, p. 541
Aurococcus Winslow and Rogers, 1906, p. 540
Myxokokkus Gonnermann, 1907, p. 883
Pedioplana Wolff, 1907, p. 9
Lactosarcina Beijerinck, 1908, p. 359
Tetradiplococcus Bartoszewicz and Schwarzwasser, 1908, p. 614
Liquidococcus Jensen, 1909, p. 305
Siderocapsa Molisch, 1909, p. 29
Metacoccus Conn, 1909, p. 12
Solidococcus Jensen, 1909, p. 332.
Sporosarcina Jensen, 1909, p. 340
Diplostreptococcus Lingelsheim, 1912, p. 494
Planomerista Vuillemin, 1913, p. 525
Enterococcus (Thiercelin) Rougentzoff, 1914, p. 648
Macrococcus, Coccus, Meningococcus, Kokkus, Galactococcus, etc. of many authors.

Many of these names may be discarded at once as invalid and not entitled to generic recognition.

The following have been used only as casual designations and are not valid genera: *Gonococcus, Pyococcus, Meningococcus, Galactococcus, Enterococcus.*

The following are the names of growth forms and have never been used in a strict generic sense: *Ascococcos, Coccoglia, Coccos, Diplococcos, Gliacoccos, Megacoccos, Mesococcos, Micrococcoglia,*

Micrococcos, Monococcos, Petalococcos, Streptococcos, Streptomicrococcus, Arthro-Streptokokkus, Tetracoccus, Endostreptococcus, Mesococcus, Pseudosarcina, Monococcus, Metacoccus, Macrococcus.

The following are invalid, usually Germanic, spellings of Latin words: *Askokokkus, Diplokokkus, Mikrokokkus, Pediokokkus, Sphaerokokkus, Jodococcus, Makrokokkus, Karphococcus, Kokkus, Myxokokkus, Haematokokkus.*

The following are names of algal genera in which certain bacteria were earlier placed, and are not true bacterial genera: *Gonium, Merismopedia, Sphaerococcus, Microhaloa, Gloeosphaeria.*

The following are invalid because previously used as generic names for plants not bacteria: *Microsphaera, Merista, Haematococcus, Botryococcus, Urococcus.*

The following are subgeneric designations: *Eucoccus, Euplanococcus, Euplanosarcina, Eusarcina.*

The following names are entitled to serious consideration as possibly valid names for cocci; *Sarcina, Micrococcus, Diplococcus, Ascococcus, Leuconostoc, Chlamydatomus, Staphylococcus, Streptococcus, Gaffkya, Neisseria, Hyalococcus, Leucocystis, Botryomyces, Pediococcus, Pseudodiplococcus, Babesia, Bollingera, Perroncitoa, Schuetzia, Urosarcina, Rhodococcus, Iodococcus, Planococcus, Planosarcina, Lactococcus, Carphococcus, Pneumococcus, Albococcus, Aurococcus, Pedioplana, Lactosarcina, Tetradiplococcus, Liquidococcus, Solidococcus, Sporosarcina, Diplostreptococcus, Planomerista, Siderocapsa.*

Certain genera which have been proposed can scarcely be recognized at the present time, because of insufficient characterization by the authors. Such genera are:

Leucocystis, Chlamydatomus, Ascococcus, Babesia, Iodococcus, Haematococcus.

Tribe I. **Streptococceae** Trevisan, 1889, p. 1051, emended

Synonyms:

Eu-Ascococceae Trevisan, 1889, p. 1035, in part
Gaffkyeae Trevisan, 1889, p. 1042, in part
Paracoccaceae Winslow and Rogers, 1905, p. 1051

Cells spherical when isolated. Usually parasitic, growing well in the absence of oxygen, particularly in the presence of carbohydrates, from which acid is developed. Gas rarely produced. Many forms require special media. Abundant surface growths are rarely developed. Planes of fission are commonly parallel, resulting in the formation of pairs, or of longer or shorter chains of cells; regular packets of cells never formed. With the exception of a few strict parasites, the cells are Gram-positive. Pigment white, orange or none.

In a previous article (Buchanan, 1915, p. 541) it was suggested that the genera in this group to be recognized are *Leuconostoc*, *Streptococcus*, *Neisseria* and *Staphylococcus*.

A study of the characteristics of the genus *Neisseria* has led to the conclusion that it should be divided to form the genera *Neisseria* and *Diplococcus*, the former to include Gram-negative organisms, the latter the Gram-positive.

The following key to the recognized genera gives the most important of the differential characters.

Key to the genera of the Streptococceae

A. Cells occurring normally in chains.
  I. Usually parasitic. Not forming zoogloeal masses in sugar solutions.....Genus 1. *Streptococcus*
  II. Saprophytic, occurring in cane sugar solutions in zoogloeal masses. Genus 2. *Leuconostoc*

B. Cells not occurring usually or characteristically in chains.
  I. Parasitic. Cells in pairs, growth as a rule meagre. No pigment formed.
    a. Gram-positive.....Genus 3. *Diplococcus*
    b. Gram-negative.....Genus 4. *Neisseria*
  II. Cells in irregular groups, usually parasites, growth as a rule good, pigment usually orange or white.....Genus 5. *Staphylococcus*

Genus 1. **Streptococcus** Rosenbach, 1884, p. 22; emended, Winslow and Rogers, 1905, p. 669

Synonyms:

Sphaerococcus Marpmann, 1889, p. 121 not *Sphaerococcus* Agardh, 1821, p. 227

Arthrostreptokokkus Hueppe, 1886, p. 144.

Perroncitoa Trevisan, 1889, p. 1053

Babesia? Trevisan, 1889, p. 29
Schuetzia Trevisan, 1889, p. 1052
Lactococcus Beijerinck, 1901, p. 213
Hypnococcus Bettencourt et al., 1904, p. 55
Myxokokkus Gonnermann, 1907, p. 883 not *Myxococcus*, Thaxter, 1892, p. 403
Melococcus? Amiradzibi, 1907, p. 309
Diplostreptococcus Lingelsheim, 1912, p. 494

Usually parasitic, though able to maintain a saprophytic existence. Cells usually in chains of greater or less length, the elements of the chains sometimes arranged as diplococci, never in packets. As a rule Gram-positive. Growth on surface of usual laboratory media not luxuriant. Growth better in liquid media containing sugars, which are as a rule fermented with acid production, but rarely gas. Usually do not liquefy gelatin or reduce nitrates. No formation of zoogloeal masses in sugar solutions.

The type species is probably *Streptococcus pyogenes* Rosenbach.

Genus 2. **Leuconostoc** Van Tieghem, 1878, p. 198; emended (as *Ascococcus*), Winslow and Rogers, 1905, p. 669

Synonyms:
Ascococcus Cienkowski, 1878, p. 12
not *Ascococcus* Cohn, 1875, p. 154
Leucocystis? Schröter, 1886, p. 152

Saprophytic, usually growing in cane sugar solutions. Cells in chains or pairs. Forming large zoogloeal masses when grown in sugar solutions. Produces acid actively from carbohydrates. Some types at least are Gram-negative.

The type species is *Leuconostoc mesenteroides* (Cienkowski) Van Tieghem.

Genus 3. *Diplococcus* Weichselbaum, 1886, p. 506, emended

Synonyms:
Klebsiella Trevisan, 1885, p. 94 in part
Hyalococcus Schroeter, 1886, p. 152
Pseudodiplococcus Bonome, 1888, p. 321
Pneumococcus? Schmidlechner, 1905, p. 291

Parasites growing poorly or not at all on artificial media. Cells usually in pairs, capsulated. Fermentative powers high, most strains forming acid in dextrose, lactose, saccharose and inulin. The cells are Gram-positive.

The type species is *Diplococcus pneumoniae* Weichselbaum. It is possible that this genus should be combined with *Streptococcus.*

Genus 4. **Neisseria** Trevisan, 1885, p. 105

Synonyms:

Diplococcus Weichselbaum, in part

Parasites, growing poorly in most laboratory media. Cells usually in pairs, flattened, coffee-bean shaped. Gram-negative. As a rule showing considerable fermentative power in carbohydrate media.

The type species is *Neisseria gonorrhoeae* Trevisan.

Genus 5. **Staphylococcus** Rosenbach, 1884, p. 19

Synonyms:

Micrococcus Cohn, 1872 b, p. 151, in part
Botryomyces Bollinger, 1888, p. 177
Botryococcus Kitt, 1888, p. 247
not *Botryococcus* Kützing, 1849, p. 892
Bollingera Trevisan, 1889, p. 1039
Gaffkya Trevisan, 1885, p. 105
Pyococcus Ludwig, 1892, p. 27
Carphococcus Hohl, 1902, p. 338
Albococcus Winslow and Rogers, 1906, p. 541
Aurococcus Winslow and Rogers, 1906, p. 205
Liquidococcus Jensen, 1909, p. 332
Indolococcus Jensen, 1909, p. 340
Peptonococcus Jensen, 1909, p. 340
Enterococcus (Thiercelin?) Rougentzoff, 1914, p. 648

Usually parasitic, cells as a rule in irregular groups or short chains, rarely in true packets, usually Gram-positive. Growth fair to good on the surface of artificial media. Sugars as a rule

fermented with acid. Gelatin commonly liquefied. Nitrates may or may not be reduced. Pigment orange or white.

It is probable that the genus should be divided upon the basis of pigment production into two genera, *Staphylococcus* and *Albococcus*, or perhaps these should rank as subgenera.

The type species is *Staphylococcus aureus* Rosenbach.

Tribe II. **Micrococceae** Trevisan, 1889, p. 1067; emended (as *Metacoccaceae*), Winslow and Rogers, 1905, p. 669

Synonyms:

Sarcineae Trevisan, 1889, p. 1044, in part
Metacoccaceae Winslow and Rogers, 1905, p. 669

Saprophytes or facultative parasites. Usually grow best under aërobic conditions. Grow well on artificial media, producing abundant surface growths. Planes of fission often at right angles, cells aggregated in groups, packets or zoogloea masses. Generally Gram-negative. Usually pigmented yellow, orange or red.

The Winslows have included three genera in this group, *Micrococcus, Sarcina* and *Rhodococcus*. A key for the quick separation of these genera may be constructed as follows:

Key to the genera of Micrococceae

A. Cells not in regular packets.
  1. Pigment generally yellow.....Genus 1. *Micrococcus*
  2. Pigment red.....Genus 2. *Rhodococcus*
B. Cells in regular packets. Pigment yellow or orange.....Genus 3. *Sarcina*

Genus 1. **Micrococcus** Cohn, 1872, p. 151, emended; Winslow and Rogers, 1905, p. 669

Synonyms:

Microsphaera Cohn, 1872a, p. 151
  not *Microsphaera* Leveille, 1851, p. 381
Ascococcus? Cohn, 1875, p. 154
Pediococcus Balke, 1884, p. 183
Merista Van Tieghem, 1884, p. 1114
  not *Merista* (Banks and Soland) Cunningham, 1839 p. 47
Planococcus Migula, 1894, p. 236

Carphococcus Hohl, 1902, p. 338
Urococcus Miquel, 1888, p. 518
not *Urococcus* Kützing, 1849, p. 206
Pedioplana Wolff, 1907, p. 91
Tetradiplococcus Bartoszewicz and Schwarzwasser, 1908, p. 614
Solidococcus Jensen, 1909, p. 332
Planomerista Vuillemin, 1913, p. 525

Saprophytes or facultative parasites. Cells in plates or in irregular masses (never in long chains or packets). Generally Gram-negative. Growth on agar abundant, with formation usually of yellow pigment. Dextrose broth as a rule slightly acid and lactrose broth neutral. Gelatin frequently liquefied.

The type species is *Micrococcus luteus* (Schroeter) Cohn.

Genus 2. **Rhodococcus** Zopf, 1891, p. 28, emended; Winslow and Rogers, 1906, p. 546

Synonyms:
Not *Rhodococcus* Molisch, 1907, p. 20

Saprophytes. Cells in groups or regular packets. Usually Gram-negative. Abundant growth with red pigment on surface of culture media. Slight acid from dextrose, none from lactose. Gelatin rarely liquefied. Nitrate usually reduced to nitrites, but not to ammonia.

The type species is probably *Rhodococcus roseus* (Flügge) Winslow.

Genus 3. **Sarcina** Goodsir, 1842, p. 432, emended; Winslow and Rogers, 1905, p. 659

Synonyms:
Lactosarcina Beijerinck, 1908, p. 359
Urosarcina Miquel, 1879, p. 517
Tetradiplococcus? Bartoszewicz and Schwarzwasser, 1908, p. 614
Planosarcina Migula, 1894, p. 236
Pseudosarcina? Maze, 1903, p. 887
Sporosarcina Jensen, 1909, p. 340

Saprophytes or facultative parasites. Division occurs under favorable conditions in three planes, producing regular packets. Usually Gram-negative. Growth on agar abundant with formation of yellow pigment. Dextrose broth slightly acid, lactose broth generally neutral. Gelatin frequently liquefied. Nitrates may or may not be reduced.

The type species is *Sarcina ventriculi* Goodsir.

Tribe III. **Siderocapseae** *Trib nov.*

Cells spherical or ovoid, non-motile, epiphytic upon the leaves and other parts of water plants. Have not been cultivated. Thick capsules enclosing the cells become encrusted with iron oxid.

One genus only has been described, *Siderocapsa.*

Genus 1. **Siderocapsa** Molisch, 1909, p. 29

One to many spherical to ovoid small cells embedded in a globule of capsular material, epiphytic on water plants. The species have not been cultivated. Best recognized by staining with Schiff's reagent. Motility not known.

The type species is *Siderocapsa Treubii* Molisch.

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